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Technical Memorandum 2-69

VISUAL CONFUSION MATRICES: FACT OR ARTIFACT?

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January 1969
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HUMAN ENGINEERING LABORATORIES

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"pattern of confusions" exists between letters of the alphabet. Implications for studies of short-term memory were discussed.

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VISUAL CONFUSION MATRICES: FACT OR ARTIFACT?*

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DENNIS F. FISHER, RICHARD A. MONTY, AND SAM GLUCKSBERG

A. INTRODUCTION

In recent years, numerous investigators of short-term memory and related phenomena have made considerable use of letters of the alphabet as stimulus items in a variety of types of studies. Many of these studies, especially those concerned with such factors as visual or auditory confusions in memory, make various assumptions concerning the probability with which perceptual confusions should occur between given letters. These assumptions are usually based on (*a*) intuitive feelings or *a priori* definitions, such as the deduction that "I" is more likely to be confused with "T" than with "O" because "I and T look alike," whereas "I and O look different" (1, 2); (*b*) confusion matrices, such as those of Gibson, Osser, Shiff, and Smith (3)—which was a by-product of a study dealing with the development of grapheme discrimination in children (6)—and of Hodge (5)—which was similarly a by-product of a study dealing with the legibility of a uniform-strokewidth alphabet (4); or (*c*) preliminary studies on a segment of the alphabet of particular interest to the investigation at hand (7).

Each of these approaches involves certain problems. The dangers in the intuitive approach are obvious. On the other hand, the utilization of such matrices as those generated by Gibson or Hodge relies on the implicit assumption that the pattern of confusions between letters of the alphabet is somewhat independent of the method of stimulus presentation employed and of the difficulty of the task. Finally, the preliminary study approach is wasteful because it requires each individual investigator to collect his own confusion data.

The major purpose of the present experiment was to determine if there is any evidence for the common assumption that there exists a basic "pattern of confusions" between upper case letters of the alphabet. The duration of stimulus exposure was manipulated to generate two confusion matrices. Further, the data were collected in a fashion that made direct comparison possible with the data previously generated by Hodge (5) and by Pew and Gardner

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(8). It was hoped that while the total number of confusions would vary between matrices, a pattern of confusions would emerge that would be independent of the exposure technique employed (tachistoscopic *versus* free viewing) and of overall error rate (manipulated by varying stimulus exposure duration).

B. METHOD

1. *Subjects*

Fifty U.S. Army enlisted men between the ages of 18 and 25, each with at least 20/20 vision (uncorrected), served as *S*s. All *S*s spoke and read English as their native language.

2. *Apparatus*

Black Chart-Pak "deca dry" upper case letters, Futura medium font, 36 point (approximately 3/8 inches high) were individually exposed through channel A of a Gerbrands two-channel tachistoscope. Each letter was mounted in the center of a 7-3/4-inch square white card. The intensity of the stimulus field was .0024 mL. A white fixation cross composed of bisecting 5/8-inch lines, 1/16 inch thick, on a black background was presented through channel B. The intensity of the cross was .001 mL.

3. *Procedure*

*S*s were dark-adapted for 25 minutes. The experimental room was darkened except for a small red pilot light.

*S*s were instructed in the operation of the tachistoscope and then received 18 practice trials with the numerals one through nine. Each numeral was presented once with an exposure time of 400 msec and once with an exposure time of 200 msec. Each stimulus presentation was preceded by a one-second exposure of the fixation cross. *S*s who failed to identify properly a majority of the numerals were disqualified from further testing. Upon successful completion of the practice trials, each *S* was given two blocks of 52 trials each (two exposures of each letter) utilizing the upper case letters described above. One block of trials was presented with an exposure time of 200 msec, the other with an exposure time of 400 msec. Blocks (exposure times) were counterbalanced across *S*s. The sequence in which the individual letters were presented was determined at random, independently for each *S*. Each letter of the alphabet was presented a total of 100 times (across *S*s) at each exposure duration.

4. *The Pew and Gardner Procedure*

Pew and Gardner (8) also generated a confusion matrix using tachistoscopic exposure of upper case letters. Black letters, prepared with a Leroy lettering set, pen #4, templet #61 0250-425 C (approximately .425 inches high) on a white background were exposed one at a time with a Gerbrands two-channel tachistoscope. In contrast to the present experiment, the testing was conducted in a lighted room. The stimulus field was at full intensity (estimated to be approximately two ft.-L), and exposure duration (manipulated by superimposing a masking field of bits and pieces of letters) was varied from *S* to *S* and within *S*s according to an iterative technique which attempted to set the error rate for each *S* at about 50 per cent. The average error rate obtained by this technique for the 20 *S*s tested was actually 45.33 per cent and the average exposure duration was 29.72 msec with a range of 15-50 msec. Each *S* viewed each letter of the alphabet 10 times, thus each letter of the alphabet was viewed a total of 200 times.

5. *The Hodge Procedure*

Hodge (5) generated a confusion matrix utilizing an altogether different procedure. Fifteen *S*s each viewed white stimulus cards each containing all 26 letters of the alphabet. The black upper case letters (approximately .24 inches high) were prepared with Leroy templet #3240-240 CL with Leroy pen numbers, 1-7. On each of 28 different cards the letters were arranged in a different random order, but were always presented in four rows of five letters each and one row of six letters. Four cards were prepared with each pen number.

The test cards and illuminating sources were mounted in an 18 by 18 by 36-inch flat-black enclosure. The luminance of the test card background was set at 25.8 ft.-L. The test cards were first shown to *S*s at a distance of 300 cm, and moved closer between trials in multiples of 10 cm; the number and size of steps varied among the *S*s. *S*'s task was to read off the letters on the test card as he recognized them. He was instructed to report a blank if he could not recognize a letter. The criterion employed was correct recognition of all 26 letters of the alphabet on two successive trials. This technique resulted in each letter being presented a total of 1218 times.

C. Results

The confusion frequencies obtained at exposure durations of 200 msec and 400 msec are presented in Tables 1 and 2 respectively. The analogous Pew

TABLE 1
CONFUSION MATRIX: STIMULUS DURATION 200 MSEC

	Stimulus letters													
R[a]	A	B	C	D	E	F	G	H	I	J	K	L	M	N
A		1	1		1	1					2	1	2	1
B				4	*5*	3	2	*5*	1	2	1	3	1	
C	1	2			3	2	3			1		*6*	1	
D		*5*	1		1		2		1	2		3		
E		1	1	1		1				1		*5*		
F	1		1	1	*8*				3	1	2	1		
G	1	*6*	*10*		1				1	3		4		
H		1			1	2			1		1		2	1
I	1	3		1	*10*	*18*		3		*22*	4	*16*	1	1
J	2	1			2	1		1	*9*			2	2	2
K	3	2	1		4	4		1	2					1
L		3	3	1	*10*	3	1	1	2	3	1			1
M	4					2		1			1	2		1
N	4	2				2	1	*10*	2	1	*14*	1	*5*	
O		3	*14*	*17*			*13*	2		3		2		
P	1	4				*14*			3		3	1	1	1
Q	1	1	2	3			3				1			
R	3	*6*			1	3		3	1	1	*9*			
S		4			1		2		1		1		1	
T			1	2	4	*13*	1		*13*	*6*	1	*8*		1
U	1	2		3	2		2	4		1		2		
V		2		1	1			2		1				
W			1											1
X	2				1				1					
Y					1	3		1	1	2	1	2	1	1
Z	3		1					1	2	1		1		
Total	28	49	37	34	57	72	30	35	44	51	42	59	17	12

and Gardner (8) data appear in Table 3; the Hodge (5) data in Table 4. The italicized cells in each matrix indicate confusions constituting five per cent or more of the number of presentations within that matrix.

In Figure 1, the per cent of total presentations of a stimulus letter that led to confusions have been plotted as a function of the stimulus-response pairs for each of the confusion matrices presented. In order to provide some indication of the extent to which similarities exist in the pattern of confusions across matrices all stimulus-response pairs that led to a five per cent level of confusions or better in Table 1 were rank ordered and plotted as shown. The corresponding levels of error for each stimulus-response pair in the other matrices were then plotted. Those letters in these latter three matrices which

TABLE 1 (*continued*)

	Stimulus letters												
R[a]	O	P	Q	R	S	T	U	V	W	X	Y	Z	Total
A				2	1	1		1		*5*			20
B	1	1		4	*13*	1	2	1	1		1	2	54
C			*2*	1	3	1	2				2	2	31
D	1	1	1		3		4	1			2	2	30
E		2										4	16
F		3		2	1			2			2	2	30
G	4		*7*	1	2		2	1	1	1	1	1	47
H		3		4		1	2	1			1	1	22
I		*11*		1	1	*35*	1	1		4	*6*	3	143
J		2		1	2	*5*	*6*	1		2	4	1	46
K				*11*		3		1		*20*	2	4	59
L		1		3		4	3	1			2	4	47
M		2			1					4			17
N		1	1	*7*	3	1		1	1	*6*	1	1	65
O		1	*30*	1	*6*		*11*	4		1	3	1	112
P				*5*	2	2			1	1		1	40
Q	3			1								2	17
R		3	1		1	1		1		*5*		1	40
S		1		2		2				3	2	4	24
T		2	1	1	1		1			2	*6*	3	67
U	2			2						1	1		23
V		3		1			2		4	3	3	1	24
W		2	3			1		4		1			13
X	1	1		1		3					3	1	14
Y		1				3		*15*	4	3		*5*	44
Z								3		3			15
Total	13	41	46	51	40	63	36	39	12	64	42	46	1060

Note: Forty-one per cent of the presentations resulted in confusions. The italicized cells contain errors constituting five per cent or more of the total presentations of a letter.

[a] R = response.

exceeded the five per cent criterion and yet are not shown in Figure 1 are shown in Figure 2, rank ordered on the basis of the level of error obtained by Pew and Gardner (8).

Finally, to facilitate further the assessment of the similarity of the results obtained from study to study, the 15 stimulus-response pairs which resulted in the most confusions are shown in rank order for each matrix in Table 5. The letters used to prepare the table were identical to those utilized in each of the studies, except for the difference in size.

TABLE 2
CONFUSION MATRIX: STIMULUS DURATION 400 MSEC

	Stimulus letters													
R[a]	A	B	C	D	E	F	G	H	I	J	K	L	M	N
A		1				1		1				1	*5*	
B	2			3	*5*	1		3		1	1	1	1	
C		1			2		4					3		
D		1			1				1	1				
E		1				3				2		3	1	
F					*5*			1	1	1				
G	1	3	*8*		2					1				
H					2	2							1	2
I		1		1	2	*18*	1	2		*24*	1	*17*		2
J				1	1	3		1	*5*			2		
K		2												1
L		2	2	2	*6*	1			2	1				
M								*6*						
N		1				1		3	1		2	1	3	
O		2	4	*6*	1	1	*10*	1	2					
P	1	3			1	*15*					2			
Q	1		4				2							
R		2				3		2	1		3			
S		2			1		1							
T		1				*5*				*7*	2		3	
U				1					1	1				
V						1					1			
W								1		1	1		2	
X	1										1			
Y	2										2		1	
Z									1	1				
Total	8	23	18	14	29	55	18	21	15	41	16	28	17	5

D. DISCUSSION

The two matrices stemming from the present study were generated under identical conditions except for a change in exposure duration. Increasing the exposure duration from 200 msec to 400 msec effectively reduced task difficulty as indicated by the decrease in total confusion errors from 41 per cent to 22 per cent. Of greater interest to the present study, however, is the extent to which the pattern of confusion errors changes as a function of exposure duration. It would appear from inspection of Figure 1 that a "best fit" curve for the 400 msec data would have the same general form as the 200 msec data (i.e., on the average the rank order position of letter pairs seems reasonably

TABLE 2 (*continued*)

	Stimulus letters												
R[a]	O	P	Q	R	S	T	U	V	W	X	Y	Z	Total
A				1						4	1	1	16
B		2		3	*9*		2						34
C	1				1	1	2					1	16
D	1	1			2		*5*					1	14
E							1	1				2	14
F		*5*			2	2					1	2	20
G				1	*9*		1				1	1	28
H				4		1	1					1	14
I		*9*		4		*34*	1			1	2		120
J				1		2	1	1	1		2	1	22
K				*11*						*14*	2	3	33
L						3	1	1				*5*	26
M									1			1	8
N		2		2		1			2	3	1		21
O		1	*18*	1	3		4			1	1		56
P			2	3				1			3		31
Q					2								9
R		2			1					2		1	17
S										1	1		6
T		1		1	1						*6*	1	28
U									1				4
V		1			1				2		2	1	9
W			1					2		1			9
X											1	1	4
Y		1		1	1			3		2			13
Z			1			1	1				1		6
Total	2	25	22	33	32	45	20	9	7	29	25	23	578

Note: Twenty-two per cent of the presentations resulted in confusions. The italicized cells contain errors constituting five per cent or more of the total presentations of a letter.
[a] R = response.

consistent). This process of averaging, however, is somewhat misleading because it eliminates local inconsistencies in the data. Assume, for example, that one wished to predict the relative confusability of two letter pairs under the 400 msec condition based on data collected at 200 msec. Looking at the 200 msec data one would predict that DO confusions occur more frequently than SB confusions. Examination of the 400 msec data, however, reveals the reverse to be true. Such inconsistencies, of course, tend to diminish as one deals with letter pairs that are more extremely separated on the curves. In short, while

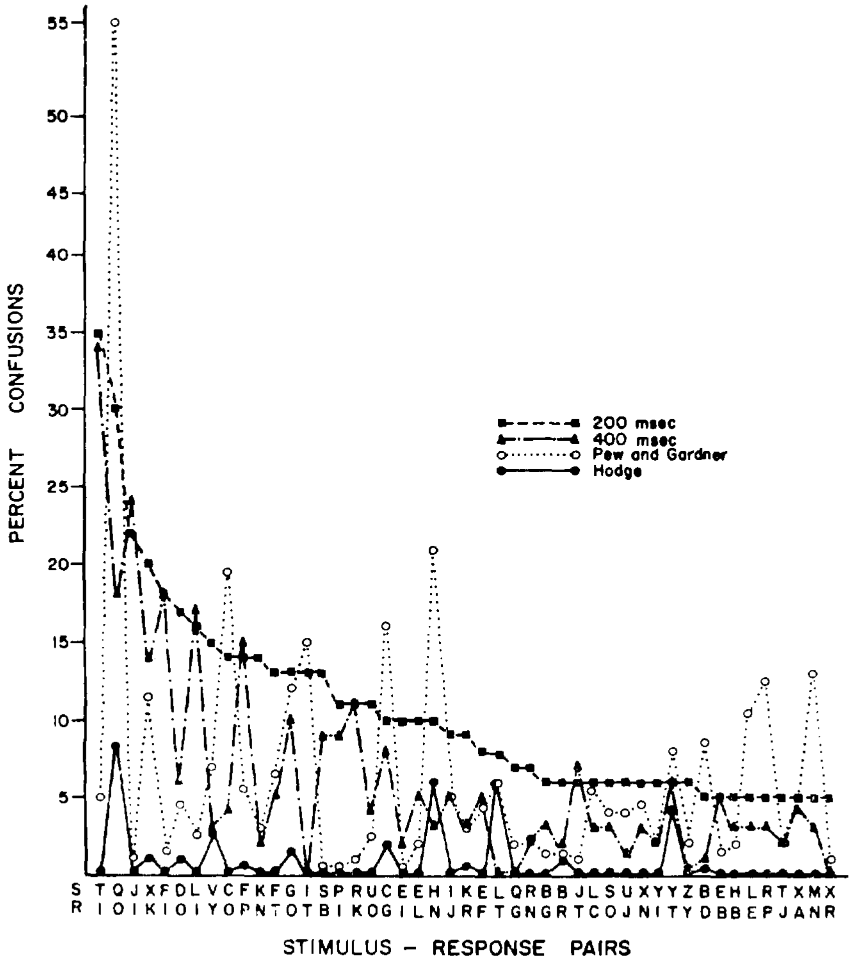

FIGURE 1
PER CENT OF TOTAL PRESENTATIONS OF EACH STIMULUS LETTER LEADING TO CONFUSIONS AS A FUNCTION OF STIMULUS-RESPONSE PAIRS AND STUDY
Only those stimulus-response pairs that led to at least a five per cent level of confusion under the 200 msec condition are included.

there is a general correspondence between the 200 msec and 400 msec matrices, predictions about specific confusions would seem to leave something to be desired.

When the results of the present study are compared with those of other investigators, the lack of similarity between matrices is even more apparent.

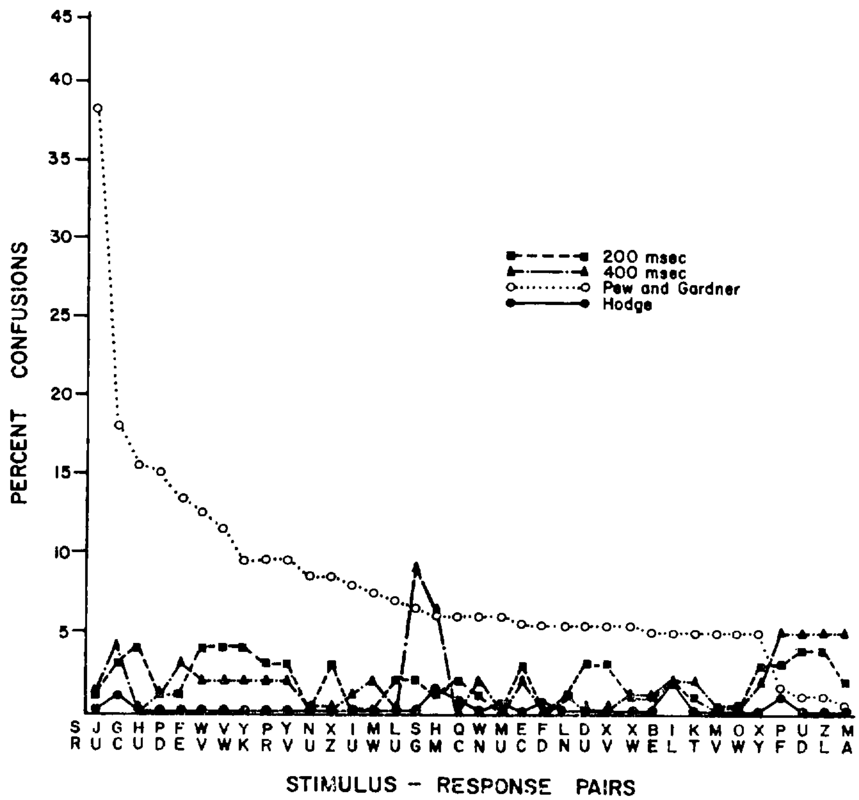

FIGURE 2

Per Cent of Total Presentations of Each Stimulus Letter Leading to Confusions as a Function of Stimulus-Response Pairs and Study

Only those stimulus-response pairs that led to at least a five per cent level of confusion and that are not shown in Fig. 1 are included.

In the case of the Pew and Gardner (8) study, task difficulty was essentially the same as the 200 msec condition of the present study (45 per cent and 41 per cent of the total presentations resulting in confusion, respectively). However, comparison of Figure 1 with Figure 2 and examination of Table 5 illustrate the almost total lack of correspondence between the patterns of error underlying these matrices. An equally discouraging result is obvious when one compares the present data with those of Hodge (5). The Hodge data fail to compare well with either of the matrices generated in the present study or with the data of Gardner and Pew.

Some of the differences between studies might be accounted for on the basis

TABLE 3
CONFUSION MATRIX: AFTER PEW AND GARDNER (1965)[a]

	Stimulus letters												
R[b]	A	B	C	D	E	F	G	H	I	J	K	L	M
A		1		2	5	5	1	3	3	1	6	4	
B			1		3	2		4		2	4	4	1
C	1	6		5	11	6	36	5	5	2	6	11	
D	1	17	4		6	11		5	8	2	2	9	
E	2	10		1		27	1	5	2		2	21	
F	1			1	9			6	5		6	4	
G	1	3	32	1	5	3		3	1		2	2	1
H	2				3	3			7	2		7	6
I	1				1	3				2	3	5	
J	1	1	2	3	4	1		5	10			3	7
K	6	3			3	5		7	5			4	3
L				1	4	1		4	10		3		1
M		1				2		12	5	1	1	2	
N	2	1		1	6	5	1	42	8	2	6	11	26
O	2	4	39	9	1	3	24	1	3	2	1	4	
P		4	1	3	3	11	1	3	6	1	4	3	
Q			9	2		1	4	1		2			
R	2	3			8	9	2	3	6	1	6	4	1
S	4	6		1	6		2		2	3	5	2	
T					7	13		7	30	2	10	12	1
U		2	1	11	3	4	1	31	16	76	6	14	12
V	2	2		1	1	1			6	8	9	2	10
W				1	1	4		4	5	2	7	2	15
X	2				2	3		3		2	9	2	
Y					1	1		2	3		8		2
Z	2				9	3			2	2	4	5	1
Total	32	64	89	43	102	127	73	156	148	115	110	137	87

of differences in the styles of letters employed. For example, in both matrices generated from the present study, JI confusions ranked high, while they did not occur at all in the top 15 ranks of either the Pew and Gardner (8) or Hodge (5) study. It can be seen from Table 5 that the "deca dry" J has a very small tail relative to the Leroy J. This factor alone could presumably result in more confusions with I, especially since the *S*s were not familiarized with the individual letters prior to their tachistoscopic exposure. Similar explanations can account for differences across studies between other pairs, such as TI where in the present study, the bar crossing the T was somewhat shorter than in earlier studies. In short then, some of the differences between the present study which used "deca dry" transfers and the previous studies both of

TABLE 3 (*continued*)

	Stimulus letters													
R[b]	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	Total
A	4		2		3		5	3	3	4	*10*	1	8	74
B			3	1	5	1		1		1	3	4	3	43
C	3	7	2	*12*	3	8	1	3	1	2	5	3	2	146
D	2		*30*	1	5	5	2	2	1		4	2	4	123
E			3		3	1	7	1		1		2	8	97
F	1		3		6		6	1			6	3	2	60
G	3	5	2	4	3	*13*	4	1	1		1	4	1	96
H	7		1		1		1	1	3	2	3	3		52
I	2		1		1		*10*	1				4	1	35
J	3	2					4	8	2	2	3	8	3	72
K	3		1		2		6		2	2	*21*	*19*	6	98
L	3						5			1	2	3	2	40
M	6				1		2		3	3	4	2	3	48
N					4		6	4	5	*12*	9	8	3	162
O			3	*110*	1	8		5	2	1	3	2	1	229
P	1				*25*		7		3	3	2	4		85
Q		8				5						2	1	35
R	1		*19*			1	4	1	1	2	2	5	7	88
S	2	1	4		4		3	1	2		2	3	5	58
T	2		4		2	1		1	2	3	8	*16*	3	124
U	*17*	1	1		1		5		2		6	2		212
V	4		1		1		3	2		*25*	*11*	*19*	3	111
W	*10*	2	1						*23*		*11*	6	6	100
X	4			1	1					1		1	5	36
Y	1				1	1	6	1	*14*	3	*10*		4	58
Z	4		2		2	2	7	1	4		*17*	8		75
Total	83	26	83	129	75	46	94	38	74	68	143	134	81	2357

Note: Forty-five per cent of the presentations resulted in confusions. The italicized cells contain errors constituting five per cent or more of the total presentations of a letter.

[a] Permission has been granted by Dr. Richard A. Pew and Gerald T. Gardner for the use of their unpublished data.

[b] R = response.

which used letters generated with a Leroy templet can be attributed to seemingly minute differences in style. Finally it should be remembered that the Hodge (5) *S*s were allowed to report a blank if they did not recognize a letter, whereas *S*s in the other two studies were required to identify every stimulus. This not only accounts for the somewhat lower confusion rate noted by Hodge but also may account for some of the differences in rank order of confusions.

TABLE 4
CONFUSION MATRIX: AFTER HODGE (1962)[a]

	Stimulus letters													
R[b]	A	B	C	D	E	F	G	H	I	J	K	L	M	N
A									1					
B					1			1						
C				3			14				1			
D		6	1				1							
E			1				1				4			
F		1			3		1			1				
G		1	23	1						1				
H		3											1	7
I														
J									3					
K	1	1			1			1					1	2
L	1		1		3		1	1	26					
M								16				1		
N		2						71					2	
O		2	3	12			16							
P				5		7		1						
Q			1	2			15							
R	1	11				2		4			8			2
S		33	1	3			41							2
T						3	1		2					
U		1					2	1					7	
V														
W		1						1					5	1
X							1				19			
Y					1	1								
Z	1	1			1						1			
Total	4	63	31	26	10	13	94	97	32	2	33	1	16	14

In summary then, there is little evidence for the common assumption that there exists a basic "pattern of confusions" between upper case letters of the alphabet. When tachistoscopic exposure and impoverished viewing conditions were used, a decrease in exposure duration resulted in the expected increase in task difficulty, but examination of the resulting matrices revealed only moderate similarity in the patterns of errors. On the other hand, when task difficulty was held constant while viewing conditions were modified (Pew and Gardner *versus* the present study), there was virtually no correspondence between the resulting pattern of confusion errors. Similarly, when the Hodge data were compared with those generated by either of the tachistoscopic techniques, correspondence was minimal.

TABLE 4 (*continued*)

	Stimulus letters												
R[b]	O	P	Q	R	S	T	U	V	W	X	Y	Z	Total
A				4			1						6
B	1			3	4			1					11
C	36		9										63
D	22		1	1	2						1		35
E										3			9
F		10				1		1					18
G	17		*73*		1								117
H				5					1				17
I	1												1
J							2			1			6
K										10			17
L					2								35
M				1					9				27
N				4		3			1				83
O			*102*	1	3		3						142
P											1		14
Q	7			1									26
R		1						1		1			31
S												1	81
T										1	56	1	64
U	1		1					8					21
V			1				1				5		7
W							1						9
X					1								21
Y						3		34	1	3			43
Z				1						5			10
Total	85	11	187	21	13	7	8	45	12	24	63	2	914

Note: Three per cent of the presentations resulted in confusions. The italicized cells contain errors constituting five per cent or more of the total presentations of a letter.
[a] Permission has been granted by the author and the publisher for the data which appeared on p. 42 of Hodge, D. C., Legibility of a uniform-strokewidth alphabet: I. Relative legibility of upper and lower case letters. *J. Eng. Psychol.*, 1963, **1**, 34-46.
[b] R = response.

It appears, then, that confusion matrices are a function of the procedures and techniques by which they are generated. Considerable research will undoubtedly be required to isolate systematically all the pertinent variables involved. Such variables as exposure duration, report technique (i.e., forced *versus* free report), and letter style clearly warrant further study. In the interim it would appear that investigators of short-term memory and related phenomena wishing to make assumptions concerning the probability with which perceptual

TABLE 5
Rank Order of Confusions for the Four Matrices

	Fisher 200		Fisher 400		Pew & Gardner		Hodge	
RANK	S R	% confusion	S R	% confusion	S R	% confusion	S R	% confusion
1	T I	35	T I	34	Q O	55	Q O	8.4
2	Q O	30	J I	24	J U	38	Q G	6
3	J I	22	Q O	18	H N	21	H N	5.9
4	X K	20	F I	18	C O	19.5	Y T	4.5
5	F I	18	L I	17	G C	18	G S	3.4
6	D O	17	F P	15	C G	16	O C	2.8
7	L I	16	X K	14	H U	15.5	V Y	2.8
8	V Y	15	R K	11	I T	15	B S	2.8
9	C O	14	G O	10	P D	15	I L	2
10	F P	14	P I	9	F E	13.5	C G	2
11	K N	14	S B	9	M N	13	O D	1.8
12	F T	13	S G	9	R P	12.5	K X	1.6
13	G O	13	C G	8	W V	12.5	O G	1.5
14	I T	13	J T	7	G O	12	G O	1.5
15	S B	13	D O	6	V W	12	H M	1.5

confusions exist between letters of the alphabet must make their test procedures identical with those accompanying an existing confusion matrix or conduct preliminary investigations with procedures comparable to those to be used in subsequent efforts.

E. Summary

Perceptual confusion matrices were generated with the use of tachistoscopic exposure of upper case letters of the English alphabet at each of two exposure durations. The resulting matrices were compared with those generated by Hodge (5) and Pew and Gardner (8). Little correspondence was noted between the pattern of confusions obtained in each study. Thus, there was no evidence for the common assumption that a basic "pattern of confusions" exists between letters of the alphabet. Implications for studies of short-term memory were discussed.

References

1. Chase, W. G., & Posner, M. I. The effect of auditory and visual confusability on visual and memory search tasks. Paper presented at the Midwestern Psychological Association, Chicago, Illinois, May, 1965.

2. CIMBALO, R. S., & LAUGHERY, K. R. Short-term memory: Effects of auditory and visual similarity. *Psychon. Sci.,* 1967, **8**, 57-58.

3. GIBSON, E., OSSER, H., SHIFF, W., & SMITH, J. An analysis of critical features of letters tested by a confusion matrix. From *A Basic Research Program on Reading,* Cooperative Research Project No. 639 (Final Report), Cornell University, Ithaca, New York, 1963.

4. GLUCKSBERG, S., FISHER, D. F., & MONTY, R. A. Brief visual memory as a function of visual and acoustic confusability. Proceedings 75th Annual Convention, American Psychological Association, Washington, D.C., 1967, 55-56.

5. HODGE, D. C. Legibility of a uniform-strokewidth alphabet: I. Relative legibility of upper and lower case letters. *J. Eng. Psychol.,* 1962, **1**, 34-46.

6. KAPLAN, G. A., YONAS, A., & SHURCLIFF, A. Visual and acoustic confusability in a visual search task. *Percept. & Psychophys.,* 1966, **1**, 172-174.

7. KUNNAPAS, T. Visual perception of capital letters: Multidimensional ratio scaling and multidimensional similarity. *Scand. J. of Psychol.,* 1966, **7**, 189-196.

8. PEW, R. W., & GARDNER, G. T. Unpublished data, University of Michigan, Ann Arbor, Michigan, 1965.

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13. ABSTRACT

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